Summer Movements of Boreal Toads (*Bufo boreas boreas*) in Two Western Montana Basins

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ABSTRACT.—The Boreal Toad (*Bufo boreas boreas*) is widely distributed in the western United States but has declined in portions of its range. Research directed at conserving Boreal Toads has indicated that their movements are largely terrestrial and often limited after the breeding season. We used a combination of stream-based netting, PIT tagging, and radio telemetry to examine patterns in captures, movements, and habitat use of Boreal Toads associated with two stream valleys in western Montana. Netting produced 514 captures of 118 adult and 203 juvenile toads from 8 July to 19 August 2003. Juveniles dominated catches initially but declined throughout the summer, whereas adult catches showed less consistent temporal trends. Of the 122 PIT-tagged toads, nearly two-thirds were recaptured 1–7 times in hoop nets, and the median total distance moved was over 1 km downstream. The median distance moved by radio-tagged toads was 2.1 km (maximum, 12.0 km) or 2.9 km (maximum, 13.0 km) if movements before and after radios were affixed are included. Over 17% of relocations of radio-tagged toads were at upland sites, 56% were in riparian zones, and 26% were in or adjacent to water. We believe that Boreal Toads in this area are engaging in long-distance movements between overwintering, breeding, and summer growth sites. Downward redistribution via streams may be common in montane habitats and warrants examination in other regions.

The Western Toad (*Bufo boreas*) is the most widely distributed amphibian in western North America (Campbell, 1970) but has declined precipitously in portions of the Rocky Mountains (Corn et al., 1997; Scherer et al., 2005). One subspecies, the Boreal Toad (*Bufo boreas boreas*), was historically viewed as common throughout much of the western United States (Corn et al., 2005). Presently, this taxon is considered a species of concern in many western states (Maxell et al., 2003; Corn et al., 2005; Keinath and McGee, 2005), and southern Rocky Mountain populations were until recently a candidate for listing under the Endangered Species Act (U.S. Fish and Wildlife Service, 2005). Many populations that crashed were apparently exposed to the fungus *Batrachochytrium dendrobatidis* (Muths et al., 2003; Scherer et al., 2005), although how the pathogen has become widespread remains uncertain (Rachowicz et al., 2006).

These declines and the threat posed by *Bufo dendrobatidis* have contributed to an urgency to increase our ecological understanding of Boreal Toads (Carey et al., 2005; Keinath and McGee, 2005), particularly those life-history characteristics related to movement. It has been shown that Boreal Toads may travel up to several kilometers between seasonal habitats but seem to maintain relatively small summer home ranges outside of the breeding season (Campbell, 1970; Jones, 2000; Muths, 2003). After breeding, adult female Boreal Toads appear to be largely terrestrial and range farther from breeding areas, presumably to foraging sites that satisfy the energetic demands associated with egg production (Carey et al., 2005), whereas males tend to be found closer to water sources and breeding sites (Jones, 2000; Muths, 2003; Bartelt et al., 2004). These observations have been based on monitoring of toads captured at or near breeding sites, in part because these animals are difficult to detect elsewhere. Yet Pilliod et al. (2002) noted that interpretations of amphibian movement behavior can be biased by restricting sampling to such individuals. This concern is pertinent because many adult Boreal Toads, particularly females, do not breed annually (Corn et al., 1997; Carey et al., 2005; Muths et al., 2006), and first-year and older juveniles may not be associated with breeding sites.

Until recently, locating Boreal Toads outside the breeding season and away from breeding sites was problematic. While quantifying summer movements of fishes in small streams in two western Montana river basins (Schmetterling and Adams, 2004; Young and Schmetterling, 2004), researchers unexpectedly encountered large numbers of Boreal Toads in streams. Based on these observations, Adams et al. (2005)

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inferred that juvenile and adult Boreal Toads make frequent and extensive stream-borne movements in the summer. In this paper, we used stream-based captures and radio telemetry to further evaluate Boreal Toad movements throughout portions of two montane stream valleys. Our objectives were to (1) describe the spatial and temporal trends in stream-based captures and telemetry-monitored movements; (2) assess the effects of climatological variables on captures and movements; and (3) compare patterns in captures and movement between sexes and between age classes.

MATERIALS AND METHODS

Study Area.—We conducted this study from 7 July to 19 August 2003 in the lower portions of Little Blue Joint Creek and Slate Creek in the West Fork Bitterroot River basin in western Montana (Fig. 1). Slate Creek drains into Painted Rocks Reservoir from the east. Little Blue Joint Creek is a tributary to Blue Joint Creek, which flows less than 1.0 km before entering the reservoir from the west. Snowmelt runoff had peaked in both systems approximately one month before the study began, and discharge was approaching summer base flow in both streams. Little Blue Joint Creek had a mean wetted width of 3.2 m, mean channel slope of 3.2%, median substrate particle size of 36 mm, and elevation of 1,449 m at its mouth. Slate Creek had a mean wetted width of 6.3 m, mean channel slope of 2.2%, median substrate particle size of 41 mm, and elevation of 1,441 m at its mouth. A forest fire in summer 2000 burned 29% of the Little Blue Joint Creek basin, and all portions of the study area underwent high-severity burns that killed virtually the entire forest canopy. By the time of the study, regrowth of nonwoody vegetation was extensive, particularly in the vicinity of the stream channel, but bare patches of soil were common in the adjacent uplands. Riparian areas had an abundance of fire-killed snags and fallen large wood, whereas upland slopes were dominated by grasses and forbs especially on southerly aspects. Fires also burned 25% of the Slate Creek basin but in an area several kilometers upstream (>5 km euclidean distance, >10 km stream distance) of the study reach. Riparian vegetation consisted primarily of large conifers—Engelmann spruce (*Picea engelmannii*) Douglas fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*)—with an understory of deciduous shrubs (*Salix* spp., *Alnus* spp., and *Cornus sericea*). The deciduous shrubs were largely replaced by grasses and forbs in upland sites. Gravel roads paralleled both stream valleys.
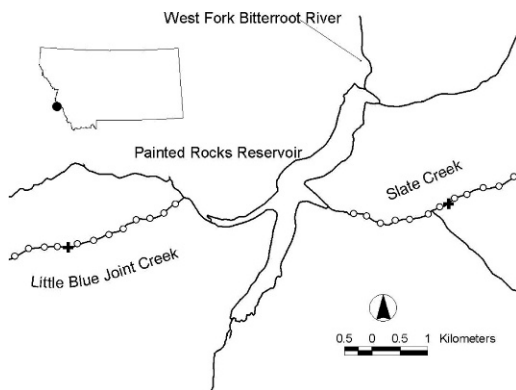

FIG. 1. Hoop-net locations (circles) and environmental monitoring station (crosses) in Little Blue Joint Creek and Slate Creek in the West Fork Bitterroot River drainage of southwestern Montana. The West Fork Bitterroot River flows north. Hoop nets were distributed at 1/3-km intervals.

Other amphibians and reptiles present in the area included Columbia Spotted Frog (*Rana luteiventris*), Rocky Mountain Tailed Frog (*Ascaphus montanus*), Western Terrestrial Garter Snake (*Thamnophis elegans*), and Rubber Boa (*Charina bottae*). The fish community in both streams consisted of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*), Bull Trout (*Salvelinus confluentus*), Brook Trout (*Salvelinus fontinalis*), Mountain Whitefish (*Prosopium williamsoni*), Slimy Sculpin (*Cottus cognatus*), and Longnose Dace (*Rhinichthys cataractae*).

Boreal Toads typically breed shortly after snowmelt in montane habitats in the Rocky Mountains (Carey et al., 2005), which can be from May to July in Montana (Werner et al., 2004). Based on observations of breeding in late May at much lower elevations in the Bitterroot River basin (Maxell et al., 2002), we believe breeding activity is in early to mid-June in the study area. We observed tadpoles in a vernally moist wetland adjacent to the lower portion of the study reach on Little Blue Joint Creek in July 2002 but did not detect tadpoles, juveniles, or adults at this site in 2003. We did not locate any potential breeding sites associated with the study reach on Slate Creek. Furthermore, these are turbulent, fast-flowing mountain streams that are unlikely to provide suitable breeding habitat for Boreal Toads. Thus, we believe the majority of animals we sampled were not associated with large breeding sites adjacent to the study reaches.

Data Collection.—On 7 July, we installed 12 hoop nets at approximately 0.33-km intervals beginning about 333 m upstream from the mouth of each stream. These distances were measured with a hip chain while walking the

thalweg (the center of the mass of flow in the channel). This interval was selected because it was less than the median movement of individuals monitored in a previous study (Adams et al., 2005). Hoop nets were placed in the thalweg and faced upstream to capture downstream-moving Boreal Toads, which constituted the vast majority of previous catches (Adams et al., 2005). Hoop nets (Miller Net Company, Memphis, TN) were 2.0 m long with a single throat, four 30–38 cm diameter hoops, and two 1–4 m long leads. Mesh consisted of multifilament nylon netting (0.6-cm bar length). We staked hoop nets to the stream bed with 1.0–1.5 m long rebar with the leads, hoops, and a portion of the cod end extending above the water to intercept toads traveling near the surface and to permit toads to remain out of the water when captured. The net leads did not span the stream channel; hence, not all passing toads would be captured at a particular location. Furthermore, we avoided embedding hoops or leads in the substrate to reduce fish captures. As flows declined during the summer, nets were sometimes moved laterally into swifter and deeper portions of the current.

Nets were checked at least daily until removed on 19 August. All captured toads were measured with calipers (snout–vent length, mm) and weighed (g, with a spring scale), sexed, checked for marks or marked, and released downstream of the net. We inferred from previous surveys in these basins (Adams et al., 2005) and elsewhere (Olson et al., 1986; Carey et al., 2005) that toads ≤55 mm were juveniles. Sex was determined based on a combination of attempts to induce vocalization and the presence of darkened nuptial pads on the inner toes of the front legs (Campbell, 1970; Hammerson, 1999). Toads >40 mm received a uniquely coded passive integrated transponder (PIT) tag implanted dorsally beneath the skin (Camper and Dixon, 1988) and all toads were given a toe clip. Absence of a PIT tag in toe-clipped individuals >40 mm was treated as evidence of tag loss. Finally, to examine diel patterns in captures, on five dates between 27 July and 9 August, we checked the hoop nets in each stream twice—once in the morning and once in the evening—on the same day.

To evaluate overall movement and habitat use, we attached transmitters to 10 Boreal Toads captured in hoop nets (five in each stream, of which eight were male and two female). We attached transmitters to nine toads between 15 and 17 July and one toad on 22 July distributed among toads caught in different nets. Each toad also received a PIT tag. Radio transmitters (1.8 g, Lotek Wireless, Newmarket, ON, Canada) emitted a unique, coded signal every 5 sec

at 150 MHz. We epoxied each radio transmitter to a 7.5 mm wide hook-and-loop strap (similar to Velcro[TM]) belt and attached the belt around the waist of each toad. Installation required 30–90 sec. Trailing antennas were trimmed to approximately 175 mm, a length at which signal strength was not reduced (DAS, unpubl. data). Radio transmitters and waist belts did not exceed 5% of toad body weight. We attempted to relocate radio-tagged toads at least daily (and sometimes more than once each day), to view each toad every 4–5 days, and to inspect each toad for abrasions and belt fit at least once over the course of the study, although some habitats precluded observing or handling toads for extended periods. We identified the general position of radio-tagged toads from a truck with an omnidirectional whip antenna and then pinpointed their positions on foot or from a boat by using a three-element Yagi directional antenna. Because battery life was predicted to be 21 days, we began removing transmitters from the toads after each transmitter had been deployed for about that period.

Upon finding each toad, we noted its location and habitat type. Locations were recorded with a global positioning system with a mean accuracy of 9.0 m (range, 3.1–35.0 m). These coordinates were transferred into a geographic information system (ArcView 3.2) as a shape file for analysis of movements. To determine elevation of the toad locations, we used ArcInfo to associate the points with elevation data from a 30-m digital elevation model of Montana (seamless raster layer, 1-m resolution). For each location, we described a toad as being in the water (i.e., in a stream, reservoir, or off-channel wetland), riparian zone, or uplands, based on valley morphology, vegetation, and proximity to water.

We evaluated a variety of physical variables to quantify their relation to toad captures and movements. We measured stream stage on a staff gauge located at stream km 3.0 (distance upstream from the mouth) in Little Blue Joint Creek and stream km 2.6 in Slate Creek and recorded the elevations daily. Adjacent to each staff gauge, we installed a rain gauge that was read daily and devices to record air temperature and relative humidity (Hobo Pro Series RH/ temperature meter) and water temperature (Optic Stowaway, Onset Computer Corporation, Pocasset, MA) at 1-h intervals. On 10 August, we measured channel wetted width and the portion intercepted by the net at each net site.

Analysis.—We summarized the number of captures of toads for each net and stream over the course of the study. We compared total catches of juvenile and adult toads per net using

a paired *t*-test, and evaluated relations between juvenile and adult captures using Pearson correlation. To address spatial autocorrelation in these analyses, we used a first-order auto-regressive covariance model to derive parameter and significance estimates. To derive capture efficiency, we used data from PIT-tagged toads that were recaptured at least once. The estimate of efficiency was based on the proportion of toads marked at an upstream hoop net that were intercepted by hoop nets downstream. For example, capture efficiency was 100% if every toad believed to have encountered a particular net site was captured at that site; capture efficiency was less than 100% if a toad was captured both upstream and downstream of a particular net site but not at that site. For this analysis, we could not evaluate efficiency of the upstream-most and downstream-most hoop nets. We related the percentage of stream that was sampled (net width/stream width at the net) to the number of captures and capture efficiency of each net using simple linear regression. Bartelt et al. (2004) noted that movements of Boreal Toads were largely nocturnal and influenced by nighttime relative humidity and air temperature. Thus, we used linear regression to relate captures of adult and juvenile toads in each stream to nighttime means (2200–0500 h) of relative humidity, air temperature, and water temperature, as well as stream stage. If captures were correlated with date, we subtracted predictions of the number of captures based on that regression model from the observed number of captures, and used these differences as the dependent variable in regressions with the climatological variables. Because climatological variables tend to be correlated, we examined only univariate relations with captures. The effect of measurable precipitation on number of captures was examined using a *t*-test assuming unequal variances. We also used Pearson correlation to compare captures of adult males and females.

We estimated stream-based movement based on recaptures of PIT-tagged toads and the thalweg distance between captures. To examine differences in movements between sexes and between streams, we used a Wilcoxon two-sample test because data were nonnormally distributed. There were insufficient recaptures of juvenile toads to conduct a comparable analysis between age classes.

For radio-tagged toads, we calculated movement frequency and rate, as well as net and total distance moved. Based on the precision of our equipment, we deemed movements greater than 10 m a detectable change in position. Total movement was defined as the sum of the straight-line distances between sequential radio telemetry locations for each toad over the course of the radio-tracking study and net movement as the euclidean distance between the initial capture site and final location. As above, we used linear regression to relate the percentage of radio-tagged toads that were moving in both stream valleys to date and stream stage and nighttime means of relative humidity, air temperature, and water temperature. The square roots of percentages were arcsine-transformed to achieve normality. Because relatively few toads were radio-tagged and not all such toads were relocated each day, we conducted these analyses only for the period from 17 July to 6 August when at least six of the 10 radio-tagged toads were located daily. Furthermore, to increase model power, these regressions used only physical data from Slate Creek; correlations in physical variables between streams were high (air temperature, 0.97; water temperature, 0.92, and transformed relative humidity, 0.90), and the significance of results with respect to movements of radio-tagged toads was similar for each stream. The effect of measurable precipitation on the percentage of radio-tagged toads that were moving was examined using a *t*-test assuming unequal variances. Comparisons between sexes were not done because only two females were radio-tagged. Finally, we used Pearson correlation to compare captures of toads in hoop nets in both streams to the percentage of radio-tagged toads that were moving.

Results

Stream Captures.—Over the 43-day study period, we made 514 captures of 116 adult and 203 juvenile Boreal Toads. We captured 50 adults (41 males, 9 females) and 141 juveniles in Little Blue Joint Creek and 66 adults (39 males, 27 females) and 62 juveniles in Slate Creek. The range of total captures of juvenile toads per net was 1–27 in Little Blue Joint Creek and 0–15 in Slate Creek, and of adults was 0–23 in Little Blue Joint Creek and 4–26 in Slate Creek. In Little Blue Joint Creek, there were no differences in the number of captures per net of juveniles and adults (mean and standard deviation, 12.3 ± 8.4 vs. 10.9 ± 6.6, $t_{11} = 0.50$, $P = 0.685$), whereas in Slate Creek the captures of adults were significantly greater (5.5 ± 5.5 vs. 14.2 ± 7.1, $t_{11} = -3.16$, $P = 0.009$). There was no correlation between numbers of captures of adults and juveniles per net in Little Blue Joint Creek ($N = 12$, $P = 0.20$, $r = -0.40$) or in Slate Creek ($N = 12$, $P = 0.82$, $r = 0.07$; Fig. 2).

Average wetted stream width at the net locations in Little Blue Joint Creek (2.5 m, range 1.3–3.8 m) was about half that of locations in
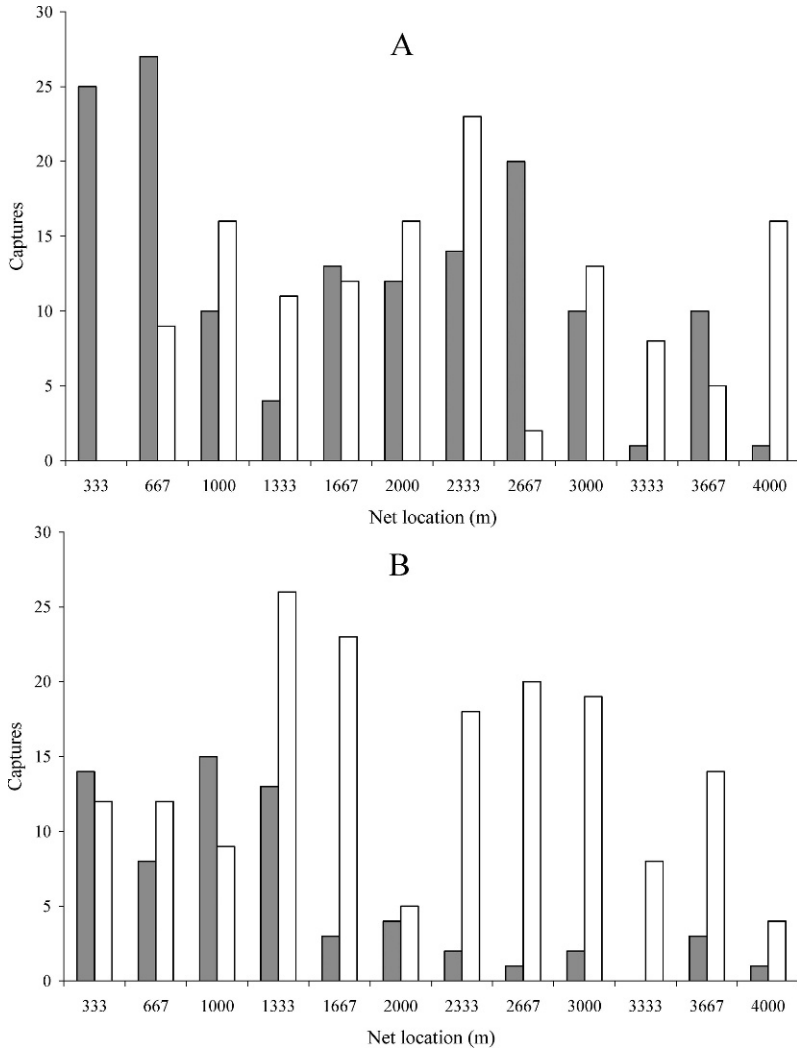
Fɪɢ. 2.   Hoop-net captures of juvenile (gray bars) and adult (white bars) Boreal Toads by net location date in Little Blue Joint Creek (A) and Slate Creek (B) in summer 2003.

Slate Creek (5.3 m, range 3.0–8.1 m), although the average portion of the channel sampled by nets in each stream was comparable (1.2 vs. 1.3 m). Hoop-net capture efficiency averaged 54% (range, 7–100%) in Little Blue Joint Creek and 61% (range, 21–100%) in Slate Creek. However, there was no relationship between total captures or capture efficiency and the proportion of stream width intercepted by a net in Little Blue Joint Creek (for captures, $N = 12$, $P = 0.961$, $r = 0.016$; for capture efficiency, $N = 10$, $P = 0.279$, $r = 0.308$) or Slate Creek (for captures, $N = 12$, $P = 0.260$, $r = 0.354$; for capture efficiency, $N = 10$, $P = 0.353$, $r = 0.329$).

Captures of juvenile Boreal Toads declined throughout the summer in both streams (Table 1, Fig. 3A), whereas captures of adult Boreal Toads either increased or exhibited no trend over this interval (Table 1, Fig. 3B). Captures of adult males and females were positively correlated (Little Blue Joint, $N = 43$, $P < 0.001$, $r = 0.56$; Slate, $N = 43$, $P = 0.019$, $r = 0.36$). On dates when hoop nets were checked in the morning and the evening, nets contained 34 Boreal Toads in the morning but only one Boreal Toad in the evening, suggesting that in-stream movements were nocturnal or crepuscular.

Climatologically influenced habitat characteristics differed between basins. In Little Blue Joint Creek, night air temperature was lower than in Slate Creek ($10.3°C \pm 2.5$ vs. $11.3°C \pm 2.2$, $t_{41} = -10.11$, $P < 0.001$), whereas night water temperature was higher ($14.1°C \pm 1.0$ vs. $12.1°C \pm 0.5$, $t_{41} = 25.13$, $P < 0.001$), which is

TABLE 1.   Correlations between adult (>55 mm) and juvenile (≤55 mm) Boreal Toad captures and date, stream stage, night relative humidity, air temperature, and water temperature in Little Blue Joint Creek and Slate Creek.

Stream	Explanatory variable	Juvenile		Adult	
		P	r	P	r
Little Blue Joint	Date	<0.001	−0.75	0.854	−0.03
	Discharge	0.468	0.11	0.994	0.001
	Night relative humidity	0.893	0.02	0.104	0.25
	Night air temperature	0.112	−0.25	0.080	0.27
	Night water temperature	0.004	−0.44	0.120	0.24
Slate	Date	0.001	−0.48	<0.001	0.49
	Discharge	0.718	−0.06	0.733	−0.05
	Night relative humidity	0.951	−0.01	0.002	0.47
	Night air temperature	0.221	0.16	0.237	−0.19
	Night water temperature	0.048	0.31	0.391	−0.14

likely because of the lack of forest canopy in the study area on Little Blue Joint Creek. Probably because of the lower air temperature, night relative humidity was higher at Little Blue Joint Creek than at Slate Creek (retransformed mean values, 90.7% ± 5.8 vs. 87.0% ± 7.7, t_{41} = 6.64, P < 0.001).

Climatological variables explained little of the variation in toad captures (Table 1). In both streams, captures of juvenile toads were negatively correlated with date, whereas captures of adult toads in Slate Creek were positively correlated with it. Mean nighttime water temperature was negatively correlated with juvenile captures in Little Blue Joint Creek and positively correlated with juvenile captures in Slate Creek, whereas mean nighttime relative humidity was positively correlated with adult captures in Slate Creek; no other comparisons were statistically significant. On average, more adult toads were captured on days with rain than on those without it (seven days vs. 36 days for Little Blue Joint Creek, nine days vs. 34 days for Slate Creek), although this difference did not achieve statistical significance for either stream (Little Blue Joint Creek, 5.0 ± 2.6 vs. 2.7 ± 1.9, t_7 = −2.27, P = 0.057; Slate Creek, 5.9 ± 3.6 vs. 3.4 ± 2.4, t_{10} = −1.94, P = 0.082).

In Little Blue Joint Creek, we recaptured 35 (of 53) PIT-tagged Boreal Toads a median of three times (range, 1–6) over a median of 10 days between first and last capture (range, 1–25 days). The median distance moved by recaptured toads was 1,333 m (range, 0–3,333 m), and the median movement rate was 152 m · d^{-1} (Fig. 4). In Slate Creek, we recaptured 44 (of 69) tagged toads a median of three times (range, 1–7) over a median of eight days (range, 1–34 days). The median distance moved was 1,000 m (range, 0–3,333 m), and the median movement rate was 162 m · d^{-1}. There were no differences in distance moved between sexes or between

streams (Table 2). The net movement of tagged toads was overwhelmingly downstream; all toads were captured downstream of their initial capture location except two (one in each stream) that were recaptured only in the net in which they were first caught. We recaptured only six of 195 toe-clipped juvenile toads. The marking scheme did not permit quantifying the distances moved by these individuals. Only one toad, a 101-mm female recaptured in Slate Creek on 19 August, was known to have shed a PIT tag during the study.

Radiotelemetry.—We tracked each radio-tagged toad an average of 23 days (range, 12–29 days) and located each toad an average of 20 times (range, 13–26; Table 3). In addition to when a radio was first attached, radio-tagged toads were seen a mean of three times and inspected three times, and every toad was seen and handled at least once. On average, radio-tagged toads moved every two days (range, 1–10 days), and median movement rates were 97 m · d^{-1}. Radio-tagged Boreal Toads traveled a median total distance of 2.1 km (range, 25 m to 12.0 km), with a net median distance moved of 1.8 km (range, 0.3–7.4 km). Based on their capture in hoop nets, six radio-tagged toads also exhibited stream-borne movement either before having a transmitter attached or after having one removed. Assuming that these movements were entirely stream-based increased total movement by a median of 0.8 km (range, 0.3–1.7 km).

Patterns of movement were highly variable. After the initial marking, one toad remained close to the area where originally marked, three individuals moved into the uplands and rarely returned to the stream, and six ended up at similar or lower elevations after a series of water-based movements with occasional forays into the uplands. Two toads in the latter group traveled downstream to or below Painted Rocks
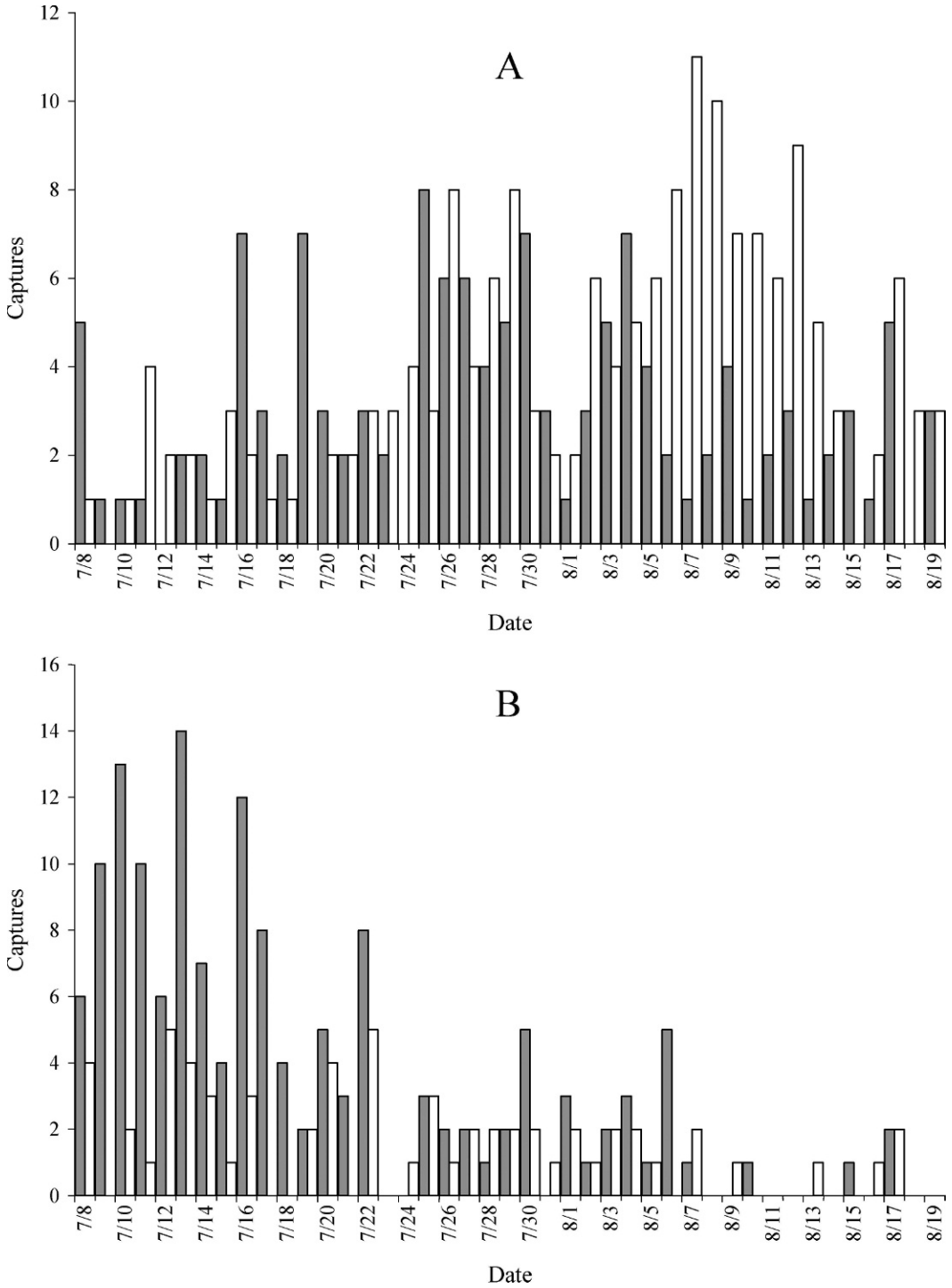
FIG. 3. Hoop-net captures of Boreal Toads by date in Little Blue Joint Creek (gray bars) and Slate Creek (white bars) in summer 2003. (A) Capture of adults (>55 mm); (B) captures of juveniles (≤55 mm).
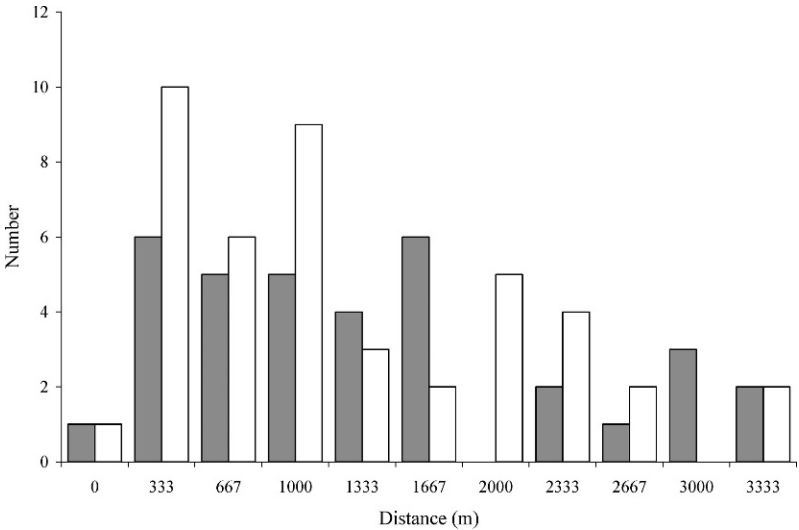
Fɪɢ. 4.   Distribution of distances moved by Boreal Toads marked and recaptured in hoop nets in Little Blue Joint Creek (gray bars) and Slate Creek (white bars) in summer 2003.

Reservoir, and two others spent time in the reservoir before moving elsewhere (Fig. 5). There may also be exchange among basins: one radio-tagged toad marked in Little Blue Joint Creek ascended the Slate Creek valley; and two of the other toads that entered the reservoir moved between the bays associated with Slate Creek and Blue Joint Creek.

Toads were located most frequently in the riparian areas (110 locations), then in or near water (stream channel, 40 locations; reservoir, 11 locations), and least often in the uplands (34 locations). After initial marking, all toads were located at least once in the water or a riparian area, whereas two toads were never located in the uplands. The percentage of radio-tagged toads moving was positively correlated with mean nighttime relative humidity ($N = 21$, $P = 0.006$, $r = 0.58$), and the percentage moving was greater on days with precipitation than on those without it (retransformed mean values, 80% ± 15 vs. 50% ± 20, $t_{11} = -2.95$, $P = 0.013$). No other physical variables (or date) were related to

movements of radio-tagged toads. However, the number of adult toads captured in hoop nets was positively correlated with the percentage of radio-tagged toads that were moving ($N = 21$, $P = 0.015$, $r = 0.52$).

Dɪsᴄᴜssɪᴏɴ

As was noted in an earlier study that used hoop nets (Adams et al., 2005), the importance of stream channels as movement corridors for Boreal Toads has gone largely unnoticed. We captured over 300 individuals of both sexes and many ages after the breeding season but before metamorphosis by using upstream-facing hoop nets in stream channels and are unaware of comparable capture totals for Boreal Toads during this period made by other methods. Visual encounter surveys are often recommended for monitoring Boreal Toads in particular areas (Heyer et al., 1994), but Keinath and McGee (2005) noted that such surveys are efficient only when amphibians are clumped,

Tᴀʙʟᴇ 2.   Total distance moved by Boreal Toads marked and recaptured in hoop nets in Little Blue Joint Creek and Slate Creek.

		Distance moved (m)				
Contrast	N	Median	Minimum	Maximum	z	P
Male	51	1,000	0	3,334	0.76	0.45
Female	25	1,000	333	3,333		
Little Blue Joint[a]	35	1,333	0	3,333	0.65	0.51
Slate	44	1,000	0	3,334		

[a] Total sample sizes differ between analyses because three juvenile toads that could not be sexed were recaptured in Little Blue Joint Creek.

TABLE 3. Tracking statistics, elevation change, and distance moved by radio-tagged Boreal Toads in Little Blue Joint and Slate Creeks in summer 2003. Net distance is the euclidean distance between the first and last radio locations. Total distance is the sum of straight-line distances between sequential locations. Distance sans radio is based on hoop-net captures of radio-tagged toads either before radios were affixed or after they were removed and is not included in telemetry-based total distance.

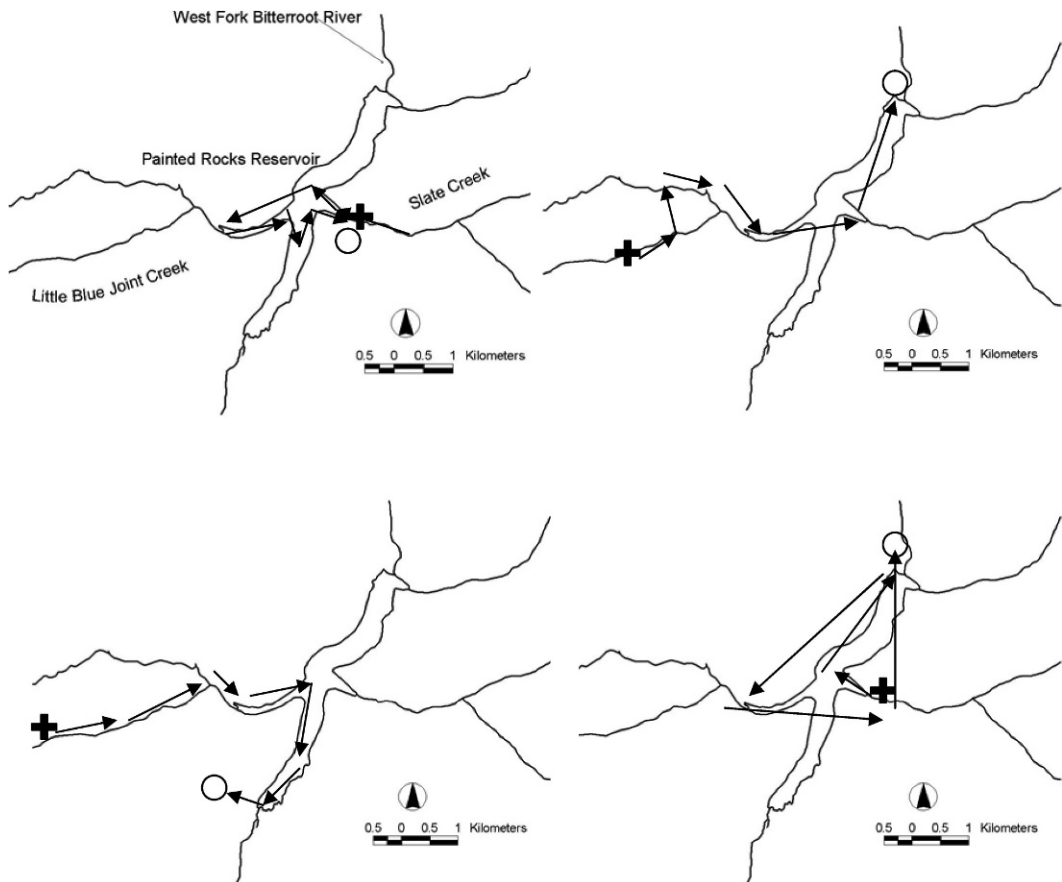| Number	Sex	Days tracked	# of locations	Elevation (m)		Distance (km)		
				Initial	Final	Net	Total	Sans radio
1	M	22	13	1,442	1,700	2.1	5.6	1.3
2	M	23	21	1,500	1,484	0.5	0.7	0.7
3	M	25	23	1,514	1,479	1.7	1.8	1.7
4	M	22	23	1,508	1,436	1.6	2.4	
5	M	29	26	1,500	1,440	1.8	7.8	
6	F	12	13	1,504	1,500	0.03	0.03	0.7
7	F	23	16	1,449	1,459	2.6	12.0	1.0
8	M	29	24	1,584	1,734	0.6	1.1	
9	M	24	20	1,616	1,467	7.4	11.0	
10	M	22	16	1,529	1,630	1.8	1.9	0.3

FIG. 5. Movements of four radio-tagged toads in Little Blue Joint Creek and Slate Creek between 15 July and 19 August 2003. Crosses indicate the initial capture location, arrows the direction of the subsequent movements and circles the last known location.

such as in breeding congregations. Although we did not conduct formal visual encounter surveys during this study, in our extensive travel by foot and automobile, we made only five observations of Boreal Toads not associated with hoop net captures or radio telemetry. Young et al. (2007) also found that after the breeding season, in-stream netting was more effective for detecting Boreal Toads than were visual encounter surveys.

Nevertheless, our enthusiasm for this approach is tempered by the inconsistency in capture efficiency among nets within each stream. In some cases, large numbers of adult toads bypassed particular nets, and this was unrelated to stream width at net sites. Although we did not measure riparian zone or valley width, we saw little evidence that either variable was related to capture efficiency (i.e., narrower riparian zones or valley locations were not associated with more captures or higher efficiencies). In addition, we can offer little insight into the spatial differences in captures between juveniles and adults other than to suggest that large numbers of captures of juveniles in certain nets may reflect their proximity to natal sites, but this pattern might only apply to first-year juveniles whose post-metamorphic migrations during the previous autumn had been limited. Addressing variation in capture efficiency and adult-juvenile captures will be important in attempting to develop stream netting as a monitoring or detection method.

However, trends in captures may be related both to changes in capture efficiency and to life-history patterns. Net width generally approached 50% of wetted stream width in Little Blue Joint Creek, which facilitated sampling from the deepest and swiftest portion of the channel throughout the study and may have contributed to the lack of a temporal trend in the daily capture rate of adult Boreal Toads in that stream. In contrast, hoop nets typically sampled less than 25% of the wetted width of Slate Creek, and seasonal declines in discharge, coupled with minor shifts in net position to sample more of the thalweg, may explain the increase in adult captures over most of the summer. Nonetheless, captures appeared to be declining in Slate Creek during the last 10 days of the study, but we were unable to conduct additional sampling to verify this trend.

Captures of juvenile toads had effectively ceased in both streams by mid-August, despite that most of the toads captured over the course of the study had been juveniles. When uncorrected for date, their capture in each stream was positively correlated with stream stage, but this was probably an artifact of the strong negative correlation between stream stage and date (for both streams, $r < -0.90$). The decline in captures and paucity of recaptures of juvenile toads over the course of the study implies that their in-stream movements may be largely passive. This may be a product of the incidental interception by the stream channel of dispersing juveniles (Sinsch, 1997) and their downstream transport while crossing the channel. Nevertheless, these conclusions pertain only to juvenile toads less than 40 mm. Of the eight juveniles that were large enough to receive PIT tags, three were recaptured and exhibited the same trend in downstream movement as adults, albeit over shorter distances (333–667 m).

Undoubtedly adults are also passively carried downstream under some circumstances, but they appear to be capable swimmers (cf. Hammerson, 1999). Several toads we handled entered and crossed the study streams in a few seconds after being released. This and other evidence—the repeated captures of adults in streams, the extended period over which they were captured, the distance moved, and the directionality of movement—leads us to conclude that adults often purposely use streams to relocate. Such movements may be bioenergetically favorable because toads can travel long distances yet avoid the exertion associated with overland travel (Adams et al., 2005). Moreover, most toad movements appeared to be at night (cf. Pimentel, 1955; Mullally, 1956; Hailman, 1984) when water temperature may exceed air temperature. During this study, air temperatures were lower than stream temperatures for several hours over the diel cycle (on average, from 2200–0800 h in Little Blue Joint Creek and from 0100–0900 h in Slate Creek). The warmer water temperatures might facilitate more rapid digestion for those toads traveling in or occupying streams (Bartelt, 2000), and nighttime travel in streams would minimize the threats from diurnal terrestrial predators (Bull, 2006).

Warm nights, high relative humidity, and precipitation have been linked with activity of this species and other amphibians, in part because these conditions are favorable for moisture retention (Hailman, 1984; Sinsch, 1988; Bartelt et al., 2004). Overall, nights with higher relative humidity and days with precipitation were related to the probability of movement of radio-tagged Boreal Toads in this study, and rainfall may have been related to capture rates in hoop nets. The positive correlation between terrestrial movements in radio-tagged toads and captures in nets also suggests that an environmental cue may be linked to movements in both environments, although it seems less likely that water balance would be

critical to toads using streams for transportation.

The movement rates we observed—medians of 97 m · d^{-1} based on radio telemetry and 152–162 m · d^{-1} based on hoop nets—are among the highest reported for Boreal Toads; most other estimates have been from 10–70 m · d^{-1} (Jones, 2000; Muths, 2003; Bartelt et al., 2004; Bull, 2006). And despite the fact that we monitored toads for less than six weeks, the median total travel distance of 2.9 km (and maximum of 13.0 km), based on both methods, is well above that noted elsewhere for toads monitored from the breeding season until much later, sometimes until hibernation. Admittedly, we assumed that hoop-net captures indicated that toads had followed the channel between captures, which we know to not always be true. Nevertheless, our estimates of movement rates and distances moved are negatively biased because we halted the movements of stream-borne toads by capturing them in hoop nets, and because we only began monitoring toads once they had been captured in a net within our study reaches.

Many of our findings with regard to movement rates and distances traveled are at odds with work conducted elsewhere, which we attribute primarily to three factors. First, because we supplemented radio telemetry observations with captures in hoop nets, we were able to include stream-based movements in our totals. To date, few researchers employing radio telemetry have followed Boreal Toads during the period in which they are moving—night—hence, detecting in-stream movements by this method would be difficult. Second, we monitored toad positions on a near-daily basis, which enabled us to avoid interpolation to estimate movement rates. In contrast, the majority of radio telemetry studies rely on observations made at intervals from a few days to a week. This protocol might be chosen because it requires less effort and increases the independence of locations for analyses of habitat use but can result in substantial underestimates of movement rates if movements between particular locations are frequent or nonlinear, as displayed by toads in this study. Third, and perhaps of greatest importance, may be the configuration of habitats in this area. Most movements, whether detected by in-stream captures or radio telemetry, were downhill or downstream and directed toward Painted Rocks Reservoir. We observed a breeding site associated with a pond at the base of the dam, and the upstream portion of the reservoir consists of an extensive shallow littoral zone that may represent a very large breeding area. Furthermore, the downstream portions of the reservoir are heavily riprapped with boulders,

and the interstitial cavities therein might afford abundant habitat for overwintering. Consequently, we hypothesize that many adult toads observed in both stream valleys may be traveling to these areas to hibernate and be near breeding sites in the following spring.

This implies that these animals also undertake long-distance movements uphill after breeding in spring, a period we did not investigate. Although such ''circular'' downhill and uphill movements across years have not been reported for Boreal Toads (but see Adams et al., 2005 for an example of an individual doing so over the course of a few weeks), Beshkov et al. (1986) observed a similar phenomenon for *B. bufo* in a Bulgarian river valley, and other observations of Boreal Toads suggest that many individuals, particularly females, may travel long distances shortly after breeding (Jones and Goettl, 1998; Bartelt et al., 2004). Because both sexes may skip years between breeding attempts (Olson, 1992; Corn et al., 1997; Muths et al., 2006), testing this hypothesis will be challenging. Nevertheless, studies of this species and other anurans (Jones, 2000; Pilliod et al., 2002; Corn et al., 2005; Funk et al., 2005a,b; Pearl and Bowerman, 2006) have revealed that complex, multiyear movement patterns may be relatively common.

Several studies have suggested that there are differences in the behavior of male and female Boreal Toads in summer, specifically that females tend to move more and be found farther from water (Jones, 2000; Muths, 2003; Bartelt et al., 2004). We found that almost three-quarters of the daytime positions of radio-tagged toads (the majority of which were male) were in terrestrial habitats, which is comparable to values observed for males elsewhere (Bull, 2006). Yet the temporal trend in in-stream captures of males and females was positively correlated, and median stream-based distances traveled by each sex exceeded 1.0 km and were similar. As posited above, if many of these individuals were preparing to breed the following spring, similar patterns in movement might be expected. However, we do not know whether most of the animals we examined had recently bred or were likely to in the subsequent year. Moreover, the male-biased sex ratios of adults captured in hoop nets, comparable to those observed at most breeding sites (Carey et al., 2005), imply either that a large proportion of females did not engage in this behavior or that mortality rates of females exceeded those of males. Further demographic and life-history studies will be necessary to resolve this issue.

In summary, we observed that Boreal Toads moved extensively and that many of these movements were via stream channels. Conse-

quently, we believe that toads may move farther and more rapidly than has been previously recognized. Yet we do not argue that all toads use streams in this way because not all locations occupied by this species (e.g., glacial cirque lakes, Muths, 2003; forested areas with vernal ponds, Bartelt et al., 2004; Great Basin foothills, Thompson, 2004) include such habitats nor do we know whether our sampling approach— monitoring only toads captured in streams— biased the sample in favor of animals employing this tactic. Regardless, past reports provide tantalizing evidence that in-stream travel has long been overlooked. For example, Campbell (1970) and Davis (2002) noted that the largest home ranges of adult Boreal Toads paralleled streams, and Carpenter (1954) reported that some toad movements appeared to follow a stream channel (also see Bull, 2006) and commonly observed toads among root tangles in and adjacent to his study stream in July and August. Thus, we encourage further exploration of stream-based netting as a method for monitoring movement patterns and the presence of Boreal Toads in montane environments. This technique has been successful in comparable habitats in southern Wyoming and northern Colorado (Young et al., 2007) and may contribute to a fuller understanding of the life histories of Boreal Toads elsewhere in their range. This may be especially pertinent to the study of juvenile toads, for which little is known because they are rarely associated with breeding sites (Carey et al., 2005; Muths and Nanjappa, 2005) or help describe the distribution and spread of the pathogenic fungus *Batrachochytrium dendrobatidis* among and away from breeding sites (Rachowicz et al., 2006).

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